Satellite Observations, Surface Signature and Properties of Nonlinear Internal Waves

Hans C. Graber and Tanos Elfouhaily*
RSMAS - Applied Marine Physics, University of Miami
4600 Rickenbacker Causeway, Miami, FL 33149-1098, USA
phone: (305) 421-4935, fax: (305) 421-4701, email: hgraber@rsmas.miami.edu
*Deceased on 25 July 2006

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LONG-TERM GOALS

The long term goal of this proposed project is to improve our understanding of the nonlinear internal waves, in particular what observations and measurements are needed to predict better existence and propagation of soliton packets as well as determine their strength (amplitude) and origin.

To improve our descriptions of nonlinear internal waves we propose a two-fold approach by acquiring satellite data such as SAR and medium resolution optical imagery and make measurements of surface and near-surface oceanic properties during the passage of internal wave soliton packets along the continental shelf.

OBJECTIVES

1) To determine the characteristics of nonlinear internal waves on the continental shelf with SAR imagery.

2) To map the occurrence and frequency of internal wave soliton packets in SAR imagery and trace their origins.

3) To determine the location and generation mechanism of nonlinear internal waves on the continental shelf.

4) To measure surface signatures and Bragg modulations during the passage of soliton packets.

5) To measure the strength, orientation and variability of the induced near surface flow during the passage of internal wave packets.

6) To measure the variability of near surface density during the passage of soliton packets.

7) To acquire additional observations of the environmental oceanic and atmospheric conditions that can be related to detection of solitons in SAR imagery.

APPROACH

During the Shallow Water 06 (SW06) experiment off the coast of New Jersey three sets of measurements will be collected for an eight week period. First, two air-sea interaction spar (ASIS)

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platforms were deployed at the center of the mooring array to provide local air-sea interaction observations. The measurements of surface and near-surface oceanic properties during the passage of IW solitons will include directional surface wave and near surface turbulence parameters. In particular, the ASIS buoys made direct measurements of directional spectra of surface gravity waves and estimates of the surface roughness that affect the scattering characteristics of sea surface. Simultaneously wind stress, atmospheric stability and near surface flow turbulence estimates will also be obtained to understand in which atmospheric windows and sea state conditions satellites and shipborne radars can observe the presence of internal waves (IWs). WOTAN sensors attached to the tether buoys will measure acoustically the intensity of ambient noise usually correlated with wave breaking and wind speed.

CSTARS will acquire an extensive set of synthetic aperture radar (SAR) and electro-optical (EO) images during the SW06 experiment. Images from satellite SARs such as RadarSat-1, ERS-2 and ENVISAT ASAR using different beam modes were scheduled for direct downlink to CSTARS that included also ScanSAR, standard and fine beam modes. We also acquired all images of MODIS on Aqua and Terra and submitted task order schedules for EO satellites SPOT 2 & 4. All images were made available in near real time (within <3 hours) and provided to ships and airborne operations to guide mobile and autonomous measurements of the IWs.

Two WaMoS marine X-band radar systems were installed on the R/V Knorr and R/V Oceanus for the duration of the SW06 experiment. The WaMoS systems were operated in short-pulse mode on the R/V Knorr to obtain unambiguous directional wave spectra and surface current information in real time by analyzing the temporal and spatial evolution of the radar backscatter from the sea surface, received in the near range of the radar (sea clutter). From this wave spectrum all important sea state parameters are derived. Also the radar images will delineate the presence of IWs in the IFOV. The WaMoS systems on the R/V Oceanus was operated in various modes, but primarily in medium-pulse to obtain better along crest coverage of IWs approaching the ship.

WORK COMPLETED

1) Deployment and recovery of two ASIS buoys during the SW06 experiment in the mid-Atlantic Bight off the New Jersey coast.

2) Direct downlink to CSTARS of several satellite sensors imaging the SW06 experimental site from mid-July to mid-September by submitting task schedules.

3) Scheduling, capture and processing of 39 RadarSat-1 SAR images.

4) Scheduling, capture and processing of 12 Envisat ASAR images.

5) Scheduling, capture and processing of 11 ERS-2 SAR images.

6) Scheduling, capture and processing of 25 SPOT-2 panchromatic images using twin cameras side-by-side.

7) Scheduling, capture and processing of 25 SPOT-4 panchromatic images using twin cameras side-by-side.

8) Installation of two WaMoS marine X-band radar system on the R/V Knorr and R/V Oceanus to collect continuous radar backscatter images and directional wave spectra and estimates of surface current vectors.

9) Developed an NLIWI specific website (password protected) to post information of satellite collections and display images and annotated images with bathymetry and SW06 mooring locations. (https://charon.cstars.miami.edu/swarm)

RESULTS

Air-Sea Interaction Measurements:

Two ASIS buoys were deployed during the SW06 experiment. One was located at the center of the mooring array and the other about 15 km westward along the cross-isobath mooring leg. The ASIS buoys provide a stable platform to measure surface fluxes and high-resolution directional wave spectra ranging in scales from the C-band Bragg waves to the dominant wind-waves. The development of the open structure concept of the air-sea interaction spar platform provides the possibility of obtaining direct measurements of directional spectra of short gravity waves and estimates of the surface roughness that affect the scattering characteristics of the ocean. The measurement of the directional properties of the centimetric to decimetric waves will be accomplished with arrays of capacitance wire gauges stretched over the 2 m cage size of the ASIS buoy and a nested smaller array of spacing 3 cm. At the same time, the spar will measure the wind stress (by direct eddy correlation), atmospheric stability and directional properties of the longer wind waves and swell. In addition two ADVs were placed in the upper ocean layer to measure the induced velocities associated with the propagation of IWs (Figure 1).

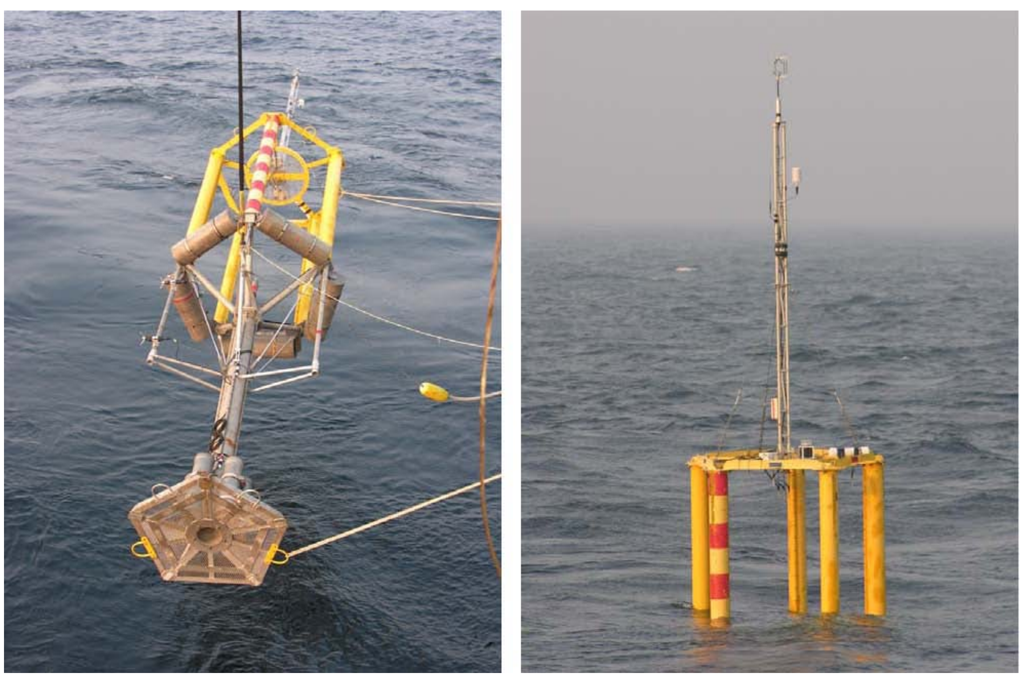

Figure 1: Left: Deployment of the ASIS buoy from the R/V Knorr. Note the two ADVs fastened to a support column on the left. Right: ASIS buoy afloat shortly before it was attached to the tether buoy.

On the tether buoys, a WOTAN sensor was deployed to measure acoustically the intensity of ambient noise which may change with the presence of IWs movement. These comprehensive near-surface current, surface wave and air-sea interaction measurements will provide an excellent opportunity to understand active microwave radiometry more fully when IW packets are present.

Satellite Imagery:

For a ten week period we collected a combination of synthetic aperture radar (SAR) and electro-optical (EO) images during the SW06 experiment. Images from satellite SARs such as RadarSat-1, ERS-2 and ENVISAT ASAR using different beam modes were scheduled for direct downlink to CSTARS commencing on July 14 until September 26. In addition to these programmed satellite passes we also acquired an extensive set of historical SAR images of RadarSat-1 and ERS-2. During the NLIWI experimental phase we had numerous situation when triplets of SAR images occurred within a timeframe of 4 hours like, for example, on August 1 in the evening RadarSat imaged the NLIWI area at 22:56:59 UTC, then three hours later ENVISAT at 02:40:26 UTC on August 2 which was followed shortly thereafter by ERS-2 at 03:10:26 UTC. These sequences of SAR images will provide good opportunities to estimate both kinematic and geographic properties of internal waves as they were propagating through the SW06 instrument array and up onto the shelf. Figure 2 shows the ground coverage of a programmed swath over the NLIWI region and a scaled reduced image with relevant isobaths as well as the location of the SW06 instrument array. Figure 3 shows the radiometrically and geometrically calibrated ENVISAT ASAR image. The image clearly presents the abundant presence of IWs in the NLIWI region.

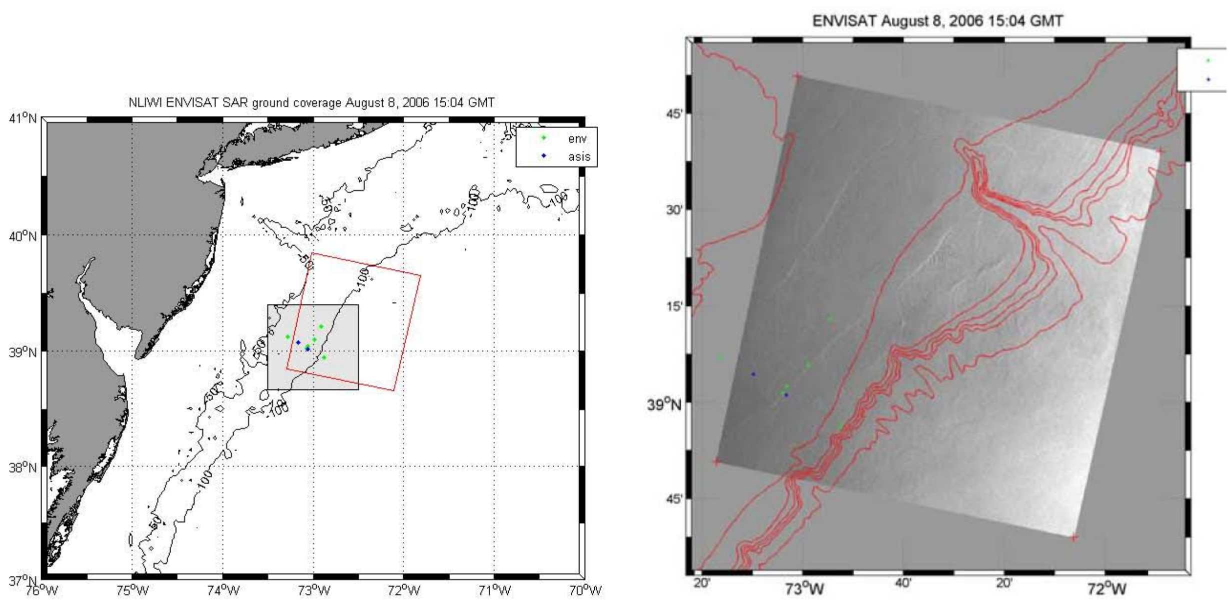

Figure 2: Left: Map displaying the location of the SW06 instrument array and the ground coverage of the ENVISAT SAR pass for 8 August 2006 at 15:04 UTC. Right: Geographically placed SAR image with overlayed isobaths and location of instrument array. Numerous internal wave packets are visible in the experimental region.

Figure 3: Radiometrically and geometrically corrected ENVISAT ASAR image for 8 August 2006 at 15:04 UTC. The image shows an abundant set of IWs up onto the shelf (northwest corner).

Marine X-Band Radar:

Two WaMoS marine X-band radar systems were installed on the R/V Knorr and R/V Oceanus for the duration of the SW06 experiment. The R/V Knorr utilizes a Furuno FR-2827 radar antenna operating at 24 rpm. The WaMoS system was placed in short pulse mode and recorded a radar image every revolution which corresponds to 2.5 seconds. The presence of IWs was easily depicted on the radar screen (Figure 4). From a sequence of radar images and knowledge of the ship's speed and course, several characteristics can be determined from the data such as number of solitons in a wave packet, wave length of each soliton, induced surface current (IW wave speed) computed from the Doppler shift.

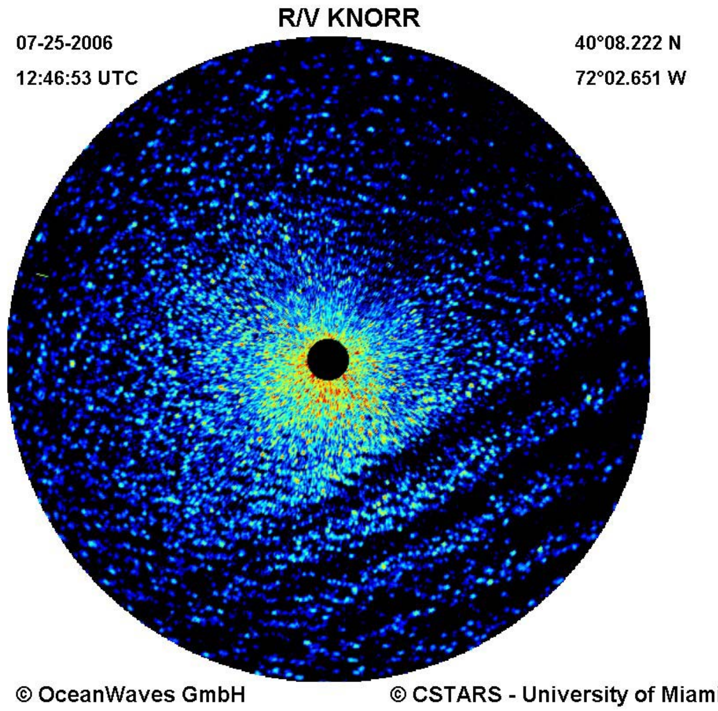

Figure 4: WaMoS radar image obtained on the R/V Knor showing the occurrence of an internal wave train from the southeast corner catching up with the ship (heading toward top of page).

IMPACT/APPLICATIONS

Improved multiple datasets measured simultaneously and coincident of internal waves will permit to predict when internal wave trains are generated given the local oceanic state.

TRANSITIONS

None. Project just started.

RELATED PROJECTS

None. Project just started.